Repairing a Failed Log Amplifier in the HP3580A Spectrum Analyzer

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Introduction

This note describes how to replace a failed hybrid log amplifier used in the HP3580A spectrum analyzer with a modern log amplifier. This note also applies to the HP3581A Wave Analyzer since it uses the identical boards of the model 3580 but the AFC function is forfeited in log mode (another board modification might restore that but that is another topic).

The failure mode was weird – the amplifier worked properly at the high end and also at the lower end of the dynamic range but was significantly in error over the 40 dB range from about -10 dB to about – 50 dB. It was also impossible to align the 1 db/division and the 10 dB/division points as there was about a 5 to 10 dB minimum error depending on other adjustments. However, in the 10 dB/division the trace appeared perfectly normal. But checking the peak level using a step attenuator clearly revealed the problem.

The solution was to either acquire a 3580A parts unit – hopefully on the cheap or fabricate a suitable replacement using modern technology. I was aware of the Analog Devices AD8307 log amplifier and after some study realized that it could make an excellent replacement. Interestingly, the part has a full-scale input of 2.5 volts peak-peak and a full-scale output of 2.5 volts DC with a 25 mV/dB slope. The log amplifier system on the 3580A A4 Detector board had a full-scale input of 2.4 volts peak-peak and a full-scale detected output voltage of 2.5 volts with a 25 mV/dB slope. The AD8307 is an excellent fit to the existing scheme on the board.

Existing log amplifier on 3580A A4 Detector Board

The 3580A A4 Detector board is shown in Figure 1. The hybrid log amplifier is the large white-ish part near the lower right and is plugged into socket pins (barely visible). The schematic diagram of the existing log amplifier on the 3580A A4 Detector board is shown in Figure 2 and consists of U1, U2, U3, U4, U5, and U11. Amplifiers U1, U2, U3, and U4 provide a saturating gain which comprises a partial log function. More amplifiers and attenuators in the hybrid module, U5, complete the log function. The input to U5 is on pin 6 and is typically set to approximately 2.4 Vpp (100 kHz) at full-scale by log gain potentiometer, R7. The output of U5 is on pin 11 and is a 2.5 Vpp square-ish wave at full-scale. The amplitude declines by approximately 0.2 volts per 10 dBV decline in input. U10 rectifies either the linear signal from U7 or the log signal from U5 depending on the Linear/Log switch setting. The full-scale output of U10 is 2.5 VDC for either linear or log mode. R8 is used to set the log intercept (offset) so that the full-scale 10dB/division and the full-scale 1 dB/division peaks coincide. R6 is used to set the linear gain so that a full-scale signal coincides with the log peaks. Absolute calibration to the top line of the CRT is done using the vertical gain and offset adjustments in the deflection amplifier on the CRT control board.

Repairing a Failed Log Amplifier in the HP3580A Spectrum Analyzer

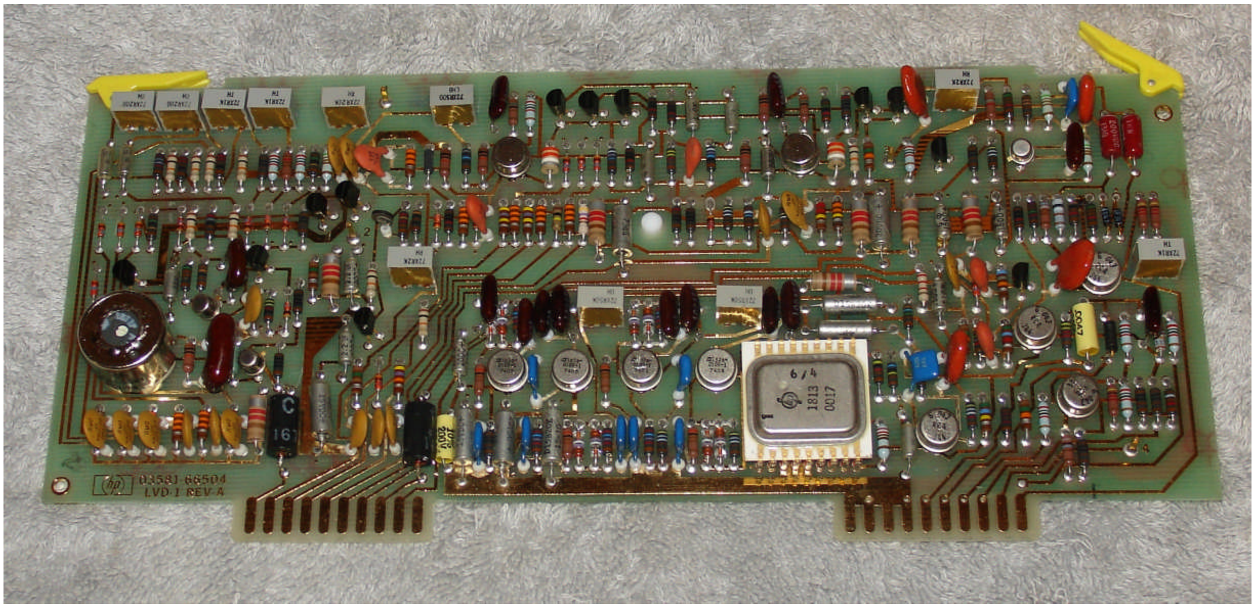

Figure 1: Picture of HP3580A A4 Detector Board

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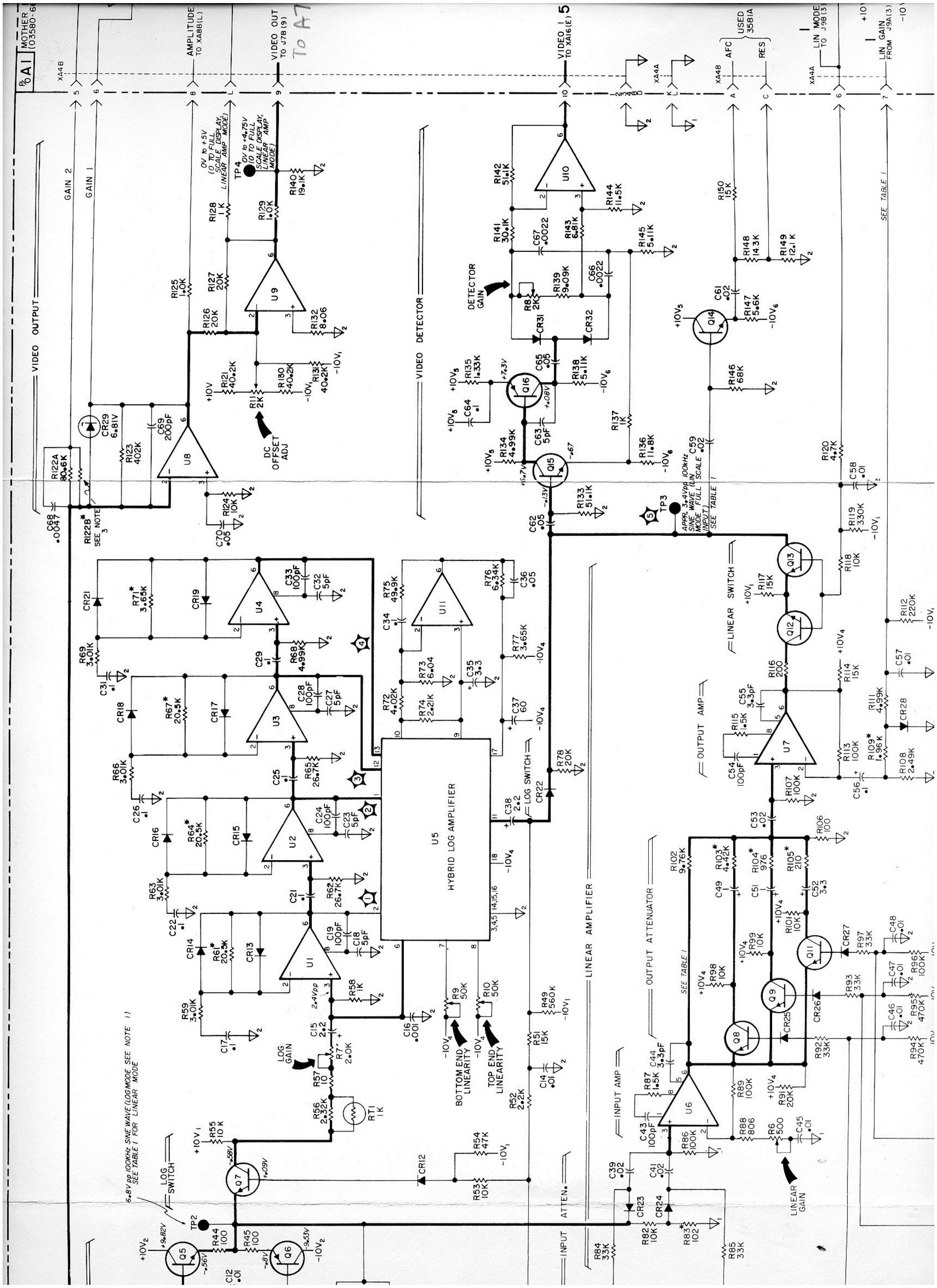

Figure 2: Schematic diagram of 3580A A4 Board log amplifier

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Modifications to adapt the A4 board to the new log amplifier

The important pins on U5 for the new log amplifier are:

3	(formerly ground) Now used for signal ground reference
4,5	Ground
6	Signal input
10	+10 volt power supply (missing connection on the schematic)
11	(formerly the output) Now used to sense linear or log mode
14,15,16	Ground
18	-10 volt power supply

The functions of U1 through U4 and U10 are not used. The output of the new log amplifier is on a wire connected to a trace to XA4B-10 that has the connection to U8-6 cut (to the lower left of TP4 – see the picture in Figure 7). The linear input (from U8 on the A4 board) is from a wire to the cut trace to U8-6.

R58 (to the lower left of U1) is removed as it is not needed for the new log amplifier. C38 (to the left of Q14) is shorted so that the new log amplifier can sense via pin 11 of the hybrid module connection the mode, linear or log, of the instrument. These components can be located in Figure 3.

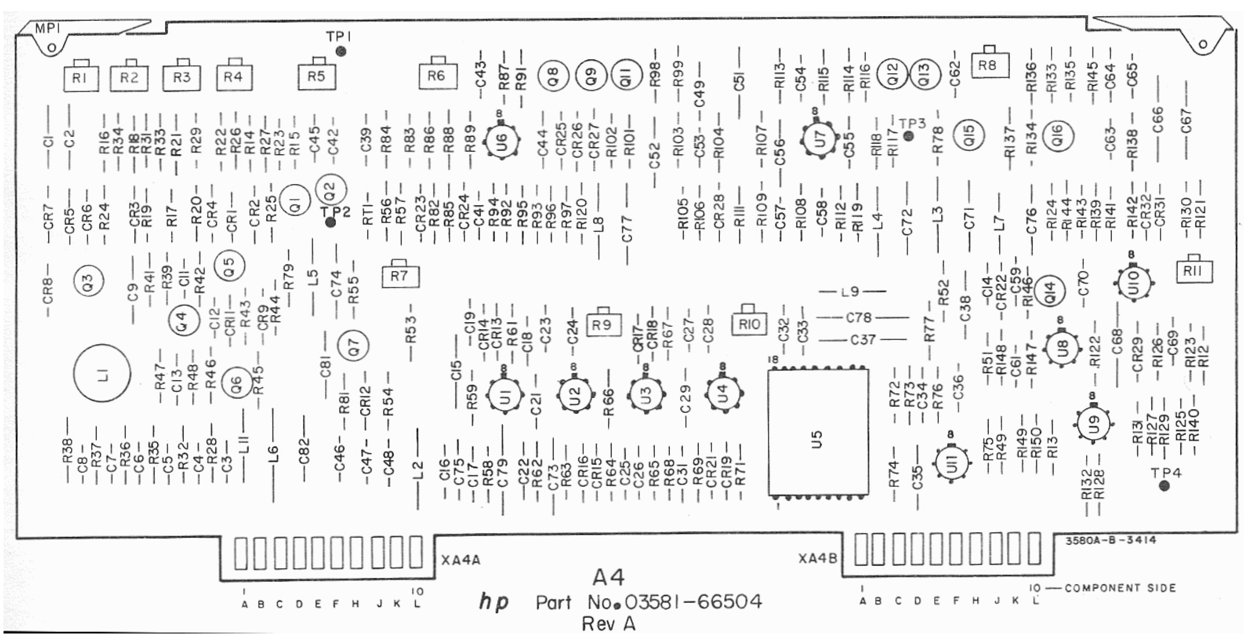

Figure 3: Board layout of 3580A A4 Detector board

Circuit description of the new log amplifier

The circuit of the new log amplifier is shown in Figures 4a and 4b.

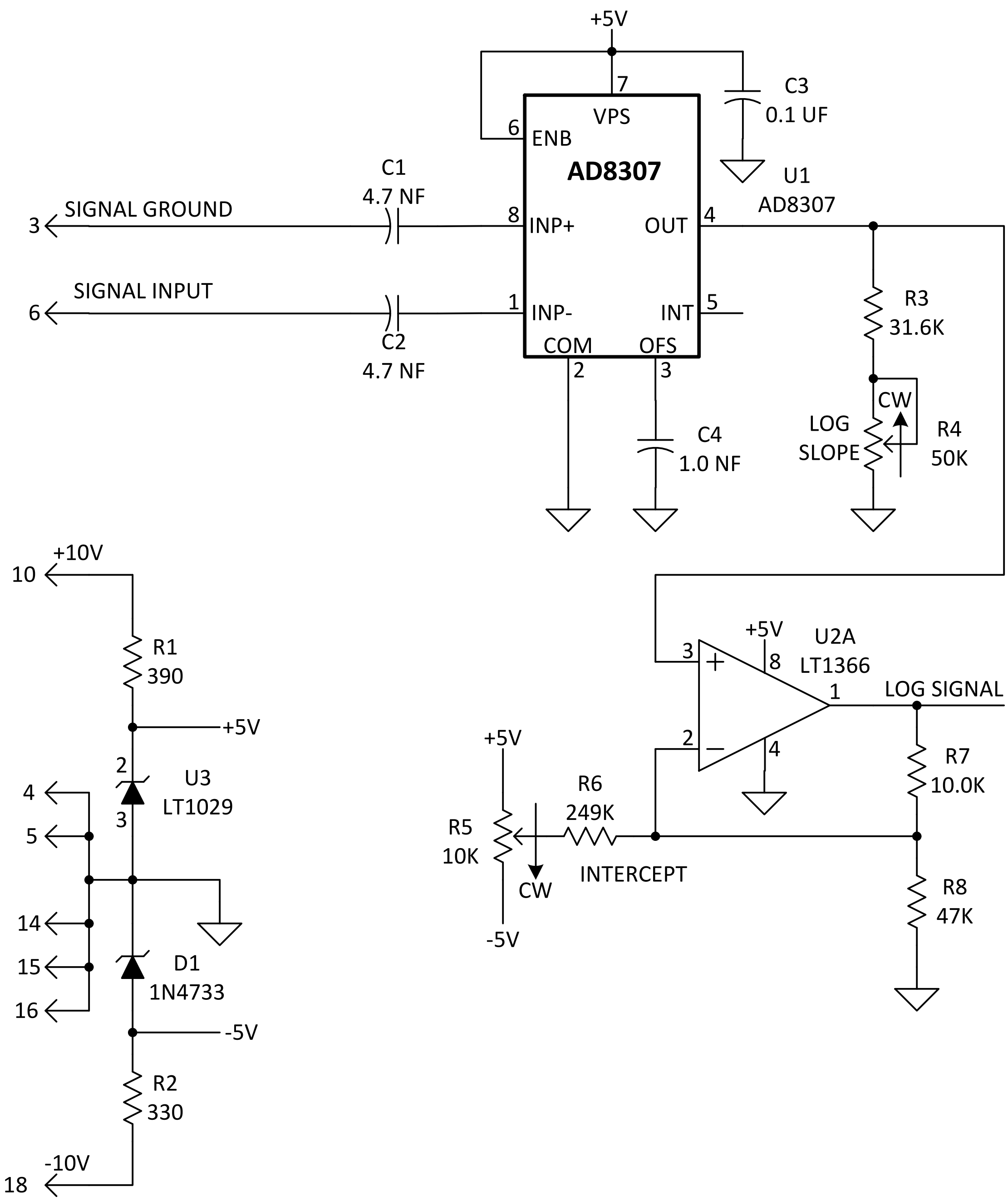

Figure 4a: Part 1 of schematic diagram of new log amplifier

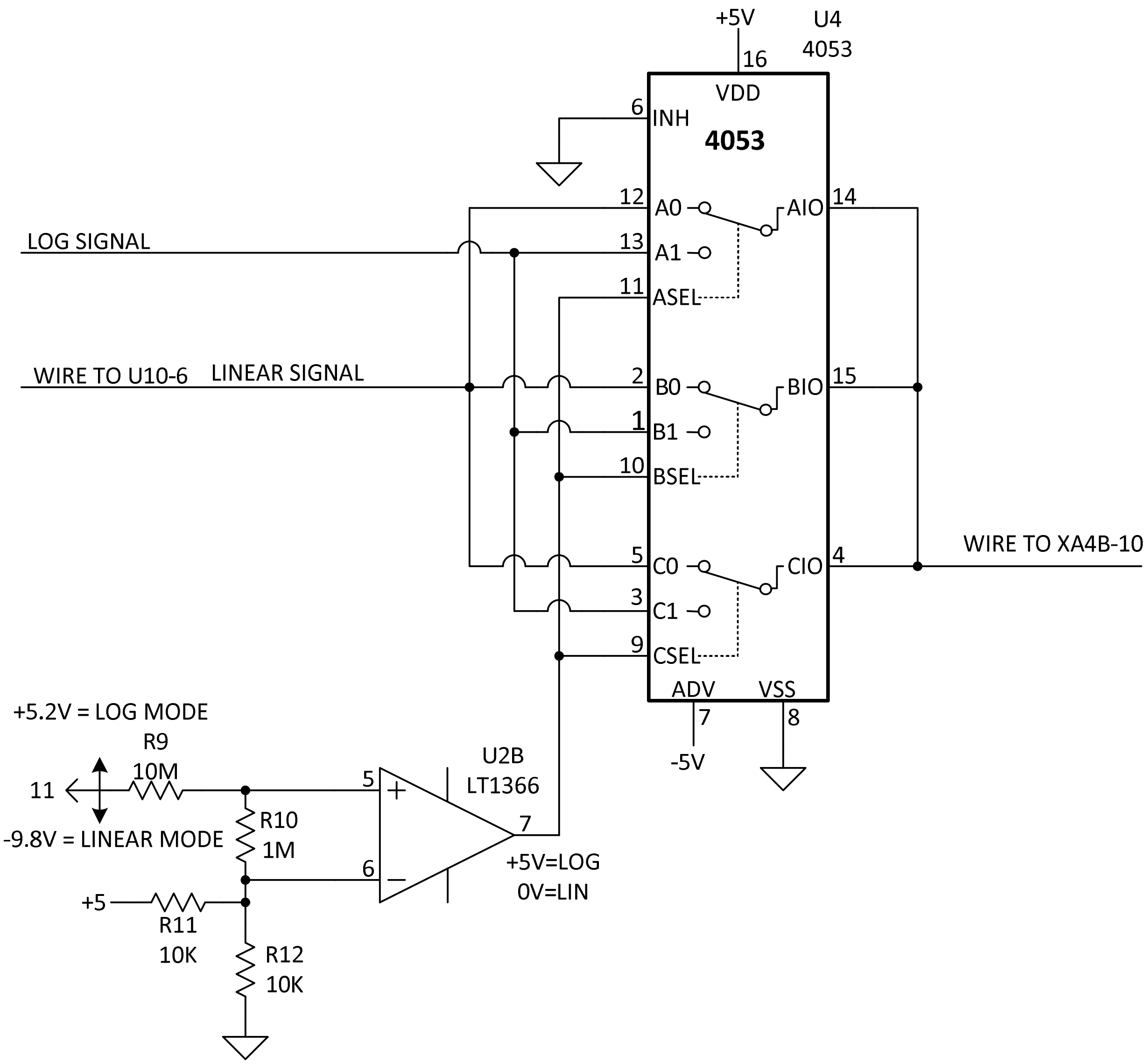

Figure 4b: Part 2 of schematic diagram of new log amplifier

A high stability +5.00 volts is provided by shunt regulator, U3. This prevents drift in the log calibration. Zener diode, D1, provides a nominal -5 volts for analog operation of the CMOS switch, U4, and for adjustment of the log intercept point.

C1 and C2 couple the 100 kHz signal to the AD8307 log amplifier. The signal is connected to the inverting input of the log amplifier and the signal ground is connected to the non-inverting input. This was done for convenience in layout – it does not really matter since the amplifier only responds to the magnitude of the differential input. C4 is necessary when using the AD8307 for lower frequency signals such as 100 kHz. That capacitor causes the time domain response of the log amplifier to be a little slow – resulting in a just noticeable display distortion at the faster sweep speeds even if the red too fast warning LED is not lit. Without the capacitor the log function becomes much distorted in the lower 40 dB range. The capacitor could probably be made smaller with less effect on the time domain response yet still provide good log performance in the lower range. The shunt resistance formed by R3 and R4 (Log Slope Adjust) lowers the output scale factor of the AD8307 to approximately 20 mV/dBV. Amplifier, U2A, amplifies the log signal to a full-scale value of 2.5 volts as needed on the A4 board. An offset is also provided to align the log intercept point.

The original output of the hybrid log converter was on pin 11 and AC coupled (capacitor C38 on the A4 board) to a diode switch driven to about 5 volts for log operation and -10 volts for linear operation. The capacitor is shorted so that the new log amplifier board can sense whether the unit is in linear or log mode. Amplifier, U2B, operates as an open-loop comparator and its output goes to +5 volts when the instrument is in log mode and 0 volts when the instrument is in linear mode. That voltage drives the select control of a triple CMOS SPST switch (all sections connected in parallel for low series resistance) to select either the linear signal (2.5 volts full-scale) produced on the A4 board or the log signal from U2A. The output of the CMOS switch goes to the connector trace to pin XA4B-10.

Construction

I built my log amplifier using thru-hole parts and point to point wiring as shown in Figure 5. A surface mount implementation would be the best method if one has the necessary equipment – The entire circuit would probably easily fit within the footprint of the original hybrid log amplifier. The thru-hole version requires significantly more area but that area is available. Black wires show the ground connections. Red wires show the +5 volt connections and violet wires show the -5 volt connections. The other wire colors are selected to make it easy to see crossovers.

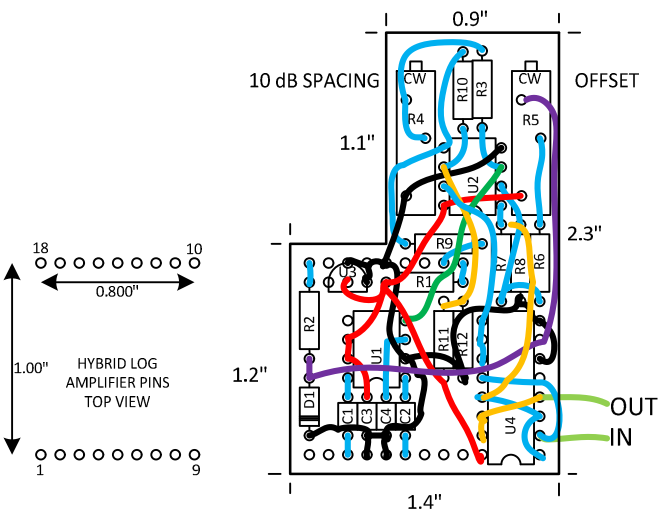

Figure 5: Component location and wiring of new log amplifier (top view)

One challenge in the construction was finding suitable pins to connect the circuit to the socket where the original log amplifier. The pins of the hybrid circuit are very similar to that of standard dual inline integrated circuits except a bit longer. I ended up using clipped leads from small leaded diodes or capacitors as those fit the sockets without being overly tight. The typical quarter-watt resistor lead is too big and would be too tight and probably damage the socket.

Figure 6 shows the completed board and Figure 7 shows the board installed on the A4 board.

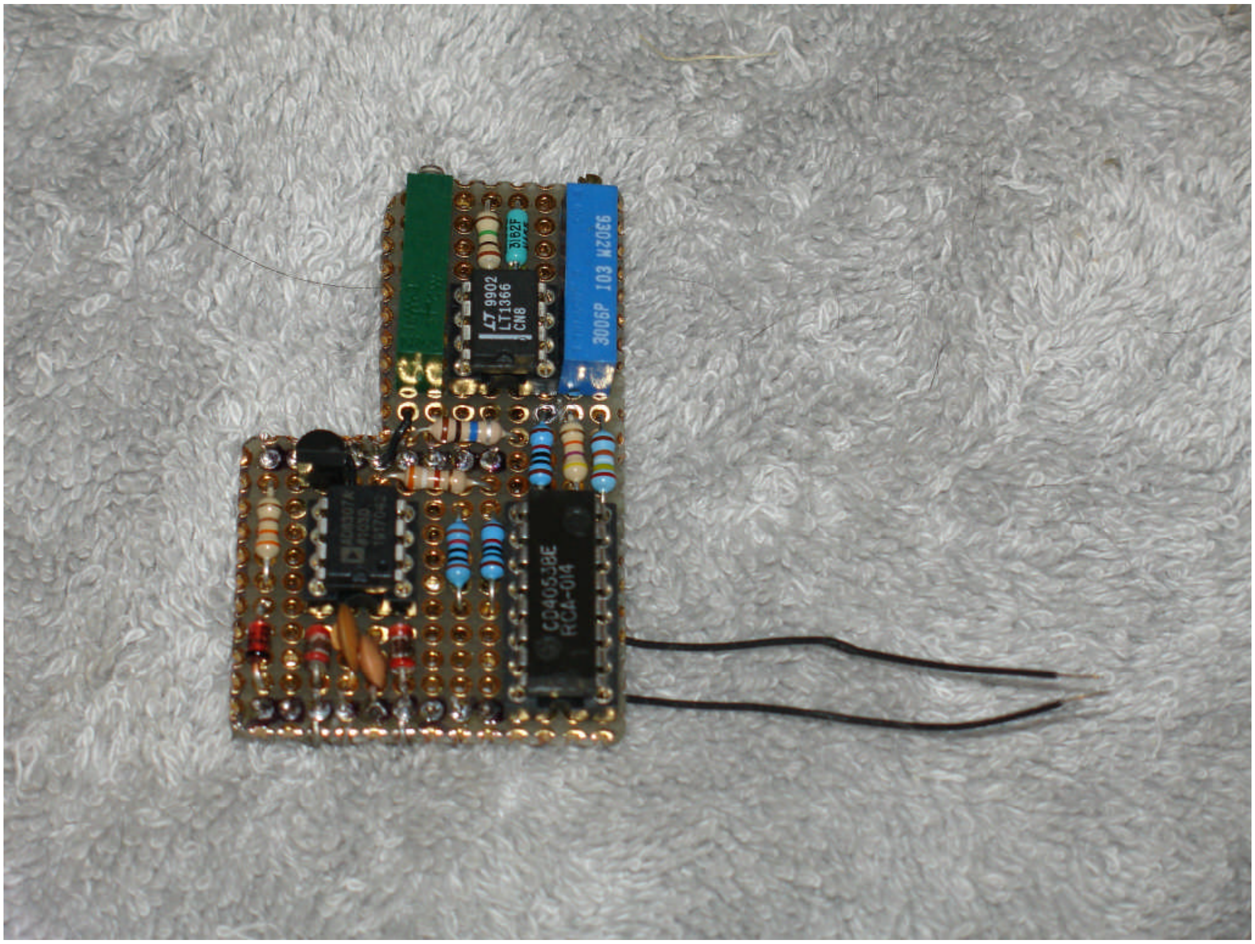

Figure 6: New log amplifier

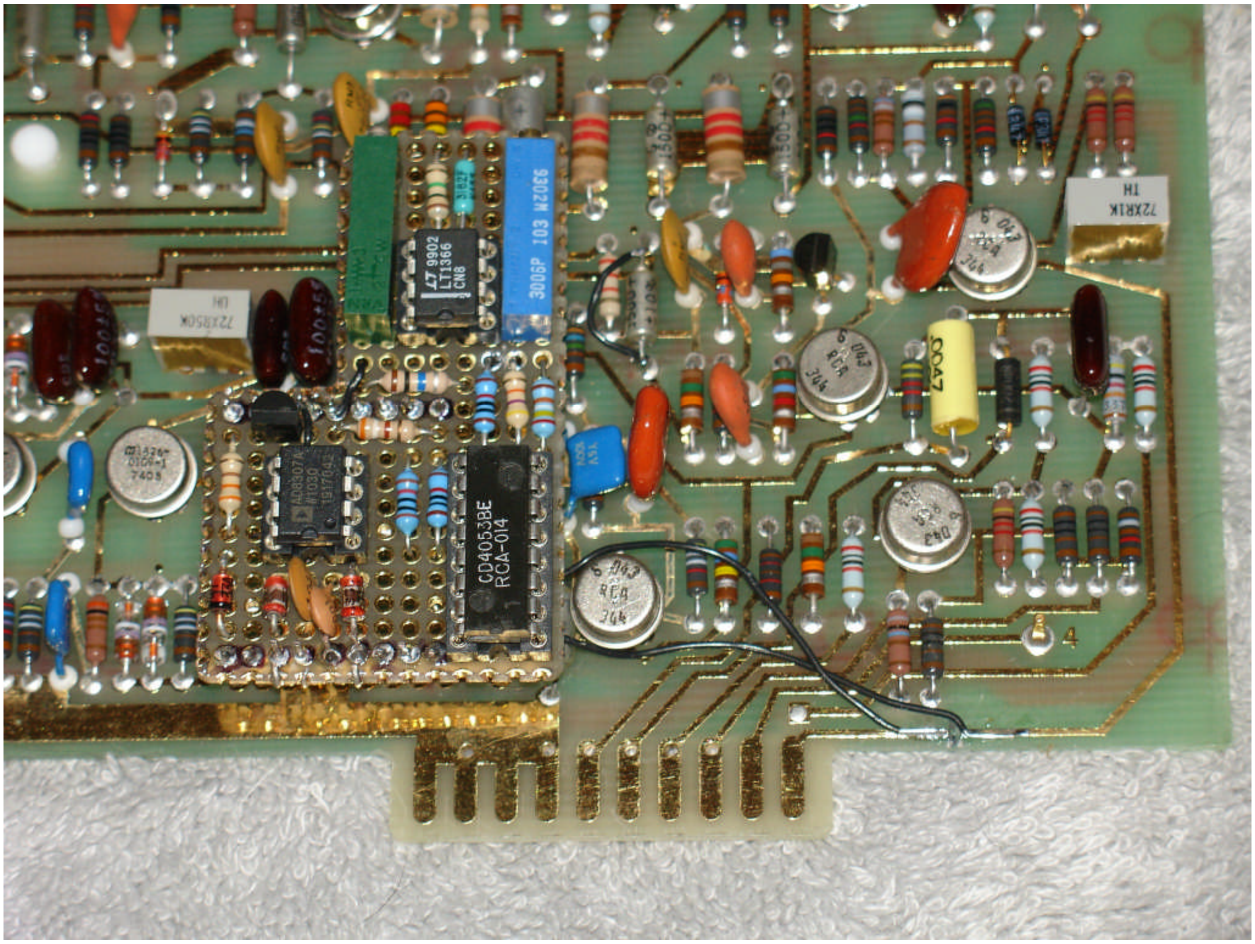

Figure 7: New log amplifier installed
Note short added across C38 (to the right of the blue potentiometer)
Note the cut etch and the two wire connections

Calibration

The calibration procedure in the manual is modified although the concept remains the same. Amplitude calibration is an iterative process in this instrument. The log slope has to be adjusted for 10 dB per major division but that adjustment interacts with the CRT vertical deflection gain. The log intercept (offset) adjustment has to be made so that the10 dB per division and the 1 dB per division intersect at the same level – ultimately the top line on the CRT. The linear gain has to be set for full-scale at the top line. The CRT gain and centering adjustments have to be made so that true zero is on the bottom line and full-scale is on the top line.

The linear adjustment is easy to make and is done last. A fair amount of iteration is generally required to make the log adjustments so those are done first. Set the controls on the 3580A to the following configuration.

ADAPTIVE SWEEP	OFF
DISPLAY	All pushbuttons released
AMPLITUDE MODE	LOG, 10 dB/division
AMPLITUDE REF LEVEL	normal
dBv/LIN – dbm 600 ohms	dBv/LIN
INPUT SENSITIVITY	0 DBV (1 volt full scale)
VERNIER (Amplitude)	CAL (Fully CW)
FREQUENCY	10 kHz
START-CTR	CTR
DISPLAY SMOOTHING	MIN
RESOLUTION BANDWIDTH	300 Hz
FREQ SPAN/DIV	1 kHz
SWEEP TIME/DIV	0.1 SEC.
SWEEP MODE	REP

1. Apply a 1.000 Vrms 10 kHz sine wave to the input. You will need a step attenuator to reduce this signal in 10 dB steps down to -80 dBV (100 uV). The signal source might have a built-in attenuator to accomplish that. You should see the 10 kHz signal with a peak near the top line of the CRT. Adjust R4 (Vertical Zero) on the A13 Deflection Amplifier board to bring the peak below the top line of the CRT if the peak is too high.

2. Set the 10 kHz CAL pot on the front panel to the approximate center of its rotation.

3. Turn R7 (log gain) potentiometer on the A4 board to maximum counter-clockwise (maximum gain). This adjustment is not needed for the new log amplifier but maximum signal input is important.

4. Press and hold the DISPLAY-CLEAR WRITE button to obtain a base line trace. Press the DISPLAY-STORE button to store the base line trace. Release the CLEAR WRITE button. You will now see a flat base line and the signal peak.

Instructions 5 through 8 are iterated until no further improvement can be made.

5. Adjust R5 (log intercept or offset) on the new log amp board so that the peaks of the 10 dB/division and 1 dB/divisions coincide – do the adjustment while on the 1 dB/division scale. If that point appears to be off the top of the screen then adjust the Vertical Zero (R4 on the A13 board) to bring it on screen. At this point it does not matter at what point on the screen the peaks are at (although it should generally be near the top), only that they are at the same height.

6. Now adjust the CRT vertical gain (R3 on the A13 board) and vertical zero (R4 on the A13 board) so that full scale deflection occurs. Initially do not be concerned with making this adjustment too precise because the adjustment will have to be revised as these steps are iterated. The goal is to be generally close with greater focus on preciseness as the adjustments converge. The result should be the base line trace at the bottom line of the CRT and the peak at the top line.

7. Using an external step attenuator, reduce the input signal to the 3580A in 10 dB steps and adjust R4 on the new log amplifier board as necessary for 10 dB/division from -10 dBV level to the -60 dBV level. This adjustment will affect the log intercept and vertical CRT calibration.

8. Repeat step 5 to this point until no further improvement can be made. If all is well then the 10 dB/division peak and the 1 dB/division peak are both at the top line of the CRT, the blank line is at the bottom of the CRT, and when the attenuator is adjusted with the unit in 10 dB/division mode that the peak is within a trace width of the -10, -20, -30-, -40, -50, and -60 dBV lines, and the peak is within 1 dB at the -70 dB level, and there is less than 2 dB error at the -80 dBV level. The floor should be at around -85 dBV or perhaps lower.

9. Apply 1.000 Vrms to the input of the 3580A and adjust R6 on the A4 board so that the linear peak is at full scale.

Amplitude calibration adjustments are now complete. Be sure to adjust R5 (10 kHz calibration level) on the A2 board as described in the manual for full-scale indication.

Performance

After calibration the new log amplifier performs very similarly to the original design but with two noticeable differences. The floor is only about 85 dB below full-scale even with maximum filtering as compared to the original that could achieve a floor of about 90 dB below full-scale when highly filtered.

Conclusion

The new log amplifier is very useful in restoring a 3580A unit with a failed log amplifier. The dynamic range of the new log amplifier is not quite as good as the original but is adequate for most situations.